

# Digital Elevation Model Extraction and Erosion Process Simulation

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**Abstract:** The study on soil erosion model has been transferred from empirical model to distributed-based spatial models. It has been very important for erosion modeling to develop the soil erosion models which could illustrate the temporal and spatial distributions of erosion process. It is a important content for current studies on erosion modeling to integrate the soil erosion model and geographic information system (GIS), which could make full of the powerful function in the field of data management, spatial analysis, three-dimensional simulation. On the basis of the study of the Digital Elevation Model extraction techniques in recent years, this paper concerns two aspects. The first is how to adequately define topographic or morphological parameters, and the second is to improve the methods of the deep information extraction on the condition of the soil erosion process in complex morphology regions. Using the information extracted from DEM, we make a connection between DEM information and erosion model, which help us to illustrate the temporal and spatial rules of soil erosion and sediment transport.

**Keywords:** erosion simulation, geographic information system (GIS), digital elevation model(DEM)

## 1 Introduction

The developing trend of soil erosion simulation will be the integration of erosion models and Geographic Information System (GIS), which can make full use of the functions of GIS in the data management, spatial analysis and visualized ability (Cbrane,T.A., 1999). Not only can GIS simulate the process of soil erosion and sediment transport, but also can afford some vital parameters that is indispensable for the calculation of models. The emphases of the soil erosion models have converted the empirical models into the process-based, spatial distribution models in the recent years. L.D.Meyer, *et al.*, (1969), G.R.Foster, *et al.*, (1982), Nearing,*et al.*, (1989) ,Finkner,S.C.,*et al.*, (1989) , Rickson,R.F.(1994) built up many successful soil erosion and sediment transport models, runoff and sediment transport as an important factor was considered in these models. Current studies of soil erosion have paid great attention to the models that reflect the process and distribution of soil erosion and sediment transport (Joao,E.M., *et al.*, 1992).

There are two main methods of extracting technique for runoff and sediment transport process as followings:

Fist one is the morphology-based method which pays great attention to simulate and compares the partial configuration in the study area. The DEM has to be pretreated firstly in order to get the DEM without any pit, which will influence the determination of the direction of runoff and the calculation of the conflux network. This method has been used by Puecker.T.K.(1975), Jenson..L.K.(1989), Band.L.K.(1986). Second one is the hydrologic-based method (O Callaghan,J.f.,1984; Marks D, 1984), which concerns more information about earth surface in the whole catchment to got conflux networks in a larger scale.

The Loess Plateau, which lies in the North of China, is one of the most serious regions of soil erosion in the world. Aiming to the characters of the Loess Plateau, researchers have got a lot of research results about soil erosion and sediment transport models, including many empirical models and process-based models (Wu Lifu,1996; Jiang Zhongshan, *et al.*,1996; Wu Faqi, *et al.*,1998; Cai Qiangguo,*et al.*,1998). Most of the soil erosion models in Loess Plateau, using an accumulative method to calculate the amount of soil erosion, are “grey box” models, which could not illustrate the spatial process of soil erosion and sediment transport. The simulation of transport of runoff and sediment is a very complex

process in a catchment in Loess Plateau; but current algorithms of the GIS software for conflux networks from grid digital elevation model (DEM), mainly using grid-based algorithms, are suitable for the plate and gentle slope regions, and not applicable for the complex physiognomy of Hilly Loess Region and may lead to the loss of significant information (Qian Yadong, *et al.*, 1997) Using the method of filtering and fill up pits in the algorithms could not get a satisfied conflux networks of runoff and sediment transport; because not only has the natural topography been changed, but also a lot of plate plots have been produced randomly and conflux directions have been mistaken (Lu Guonian, *et al.*, 1998).

The objective of the study is to modify the grids-based method, which is a traditional technique of extraction for physiognomic parameters, and simulate the conflux process of runoff and sediment on the complicated earth surface of a catchment in the Loess Plateau, and get the runoff and sediment conflux networks between plots in a catchment.

## 2 Materials and methods

### 2.1 Test site

The study area is Alastai catchment (39° 49' N, 109° 54' E), lies in the east of Dongshe City in the Inner Mongolia and covers an area of 26.7452 km<sup>2</sup>. The length of the main valley is 8.3 km, and the intensity of gullies is 3.2 km • km<sup>-2</sup>. The main soil type is the Loess. The region has a semi-arid continental climate with an average annual rainfall of 400.2 mm. The erosion modulus has 5,000 t/km<sup>2</sup>—8,000t/km<sup>2</sup>.

### 2.2 Methods

According to the complex physiognomy conditions of Hilly Loess Region, we modified the grids-based algorithms, and presented an algorithm that the conflux networks of runoff and sediment transport between plots. Through the algorithms, the conflux networks could be extracted automatically. The basic steps to calculate the conflux networks between plots are presented as followings: firstly, the definition for the configurative construct of physiognomy; secondly, the distinguishing of conflux directions of runoff and sediment transport and the extraction of conflux networks.

This study introduced the catchment structure defined by Shreve to depict the physiognomic configuration. It includes two parts in the Shreve's catchment structure: crunode collection and borderline collection. On the basis of the physiognomic lines in the Loess Plateau including the shoulder line of the valley and the bottom line of the valley, the catchment can be divided into three parts: Hilly slope, Valley slope and channel.

It is necessary to make a division of plots in a catchment in order to simulate the process of runoff and sediment transport among plots. It is a basic rule for the plots division that the divided plots should be consistent with the practical land types, that is to say, the boundaries of the divided plots should be according with the boundaries of various land types. However, it is not enough to simulate the conflux process in plots without any classification. On the condition of complex earth surface, even in a bigger land unit, the erosion energies will be varied. Therefore, the study developed a searching a scale which is the midst of the grids and the real land types, which are the indispensable step for a more accurate simulation of the conflux process.

The division of plots and the extraction of their traits are supported by IDRISI software. Based on the map of land types, slope map, slope aspect map, soil map, the map of land-unit in a catchment has been produced by using the function of GIS software including classifications, overlapping and so on. In the divided plot units, the traits of the earth surface such as slope degree, slope aspects, soil types, vegetative cover and so on could be composed in each plot unit; and each plot unit has a single trait which is different with its neighboring plots.

Based on each plot, the whole structure of physiognomic configurations can be classified into the following three types: (a) plate land: including higher plate land, such as "mao" plots; ladder plate land, such as terrace plots and level plots; lower plate land, such as the check dam plots; (b)slope land: including hilly slope and valley slope; (c) pit land: including single pit and grouped pits.

The physiognomic configurations illustrate the combination relationships of different physiognomic entities in Loess Plateau Region. The algorithms will be given according to various physiognomic configurations and their relationships.

The study used triangle irregular networks to illustrate the relative characters of point, line and face. Boolean algebra can be used to denote the afflux of runoff and efflux of runoff when runoff flows a plot, and there are boundaries including the afflux boundary, efflux boundary and transport boundary.

### **2.3 The distinguishing for directions of runoff and the extraction for conflux networks**

The study calculated the conflux network with the image type or the array type. All of the steps have been programmed by Visual C++ and Visual Basic and made a Windows-based system to calculate the conflux networks between plots automatically. The algorithm searches the start bit of each plot as an index, then begin to trace the plots one by one supported by three sub-functions, which can deal with three different physiognomies and find all the edge points of the current plot by distinguishing the points whether are afflux points or efflux points. In terms of the distribution of the conjunct length of the neighboring plots, the proportion of the area and the maximum elevation, the GIS find the maximum conflux direction as the main conflux networks of the plots. In the process of calculation, the GIS searches the plate land plots and the slope land plots firstly, then distinguishes the conflux directions between plots step by step. It is a complex process for the calculation of the pits including single pits and grouped pits. We find the exit of the pits and calculate the efflux amount through determining the lowest point of the edge neighboring edge among the plots. There are five steps as followings to distinguish conflux directions and to extract the conflux networks: First is the process of initialization; second is to calculate the conflux process in plate plots; third is to calculate the conflux of pits; fourth is to simulate the process of slope plots; fifth is to simulate the conflux process of the whole catchment.

## **3 Results and discussion**

Three vitally important parameters for the soil erosion and sediment transport models have been extracted from the conflux networks between plots.

Firstly, we extract the array relationships reflecting the sequence of the conflux of runoff and sediment for the whole catchment. Based on the conflux relationships, the programs recognize the sequence from the top of the catchment to the bottom of the catchment and determinate the automatic calculation sequence of the models.

Secondly, the network provides a distribution proportion between plots of the amount of the conflux of runoff and sediment, which is an indispensable parameter participating in the models' calculation. The proportion relationships illustrated the transpiration of matter and the exchange of energy in a catchment.

Thirdly, we extracted the main conflux routes as the slope length of the plot. The slope length parameter extracted from the networks of runoff and sediment between plots show the physiognomy characters of Hilly Loess Region.

## **4 Conclusion**

The study got the following conclusions:

According to the complex physiognomies of the Loess Plateau of China, we modified the grids-based method which is a traditional technique of extraction for physiognomic parameters, and provided the algorithms of the plots-based runoff and sediment conflux networks. The study simulated the conflux process of runoff and sediment on the complicated earth surface of a catchment, and the deeper information has been extracted automatically from the digital elevation model (DEM); then introduced the process of runoff and sediment transport to the soil erosion and sediment transport models, which is an important progress to erosion simulation. Through the combination of the networks of the runoff and sediment and the models, the relationship of runoff and sediment between upper-slope and blower-slope have been indicated more obviously in the models.

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